

R E M A R K S

The Office Action enclosed copies of the INFORMATION DISCLOSURE STATEMENT BY APPLICANT IDS forms dated October 29, 2007, August 31, 2007, August 30, 2007 and May 23, 2007; and Forms PTO/SB/08A dated March 30, 2007, with the Examiner's initials in the left column next to all of the cited publications in the IDS Forms dated October 29, 2007, August 31, 2007 and May 23, 2007 and many (but not all) of the publications in the IDS Form dated August 30, 2007 and the Forms PTO/SB/08A dated March 30, 2007.

For the reasons set forth in item no. 1 on page 2 of the Office Action, the Examiner drew a line through each of JP 49-7117, JP 54-10923, JP 54-23329, JP 55-12184, JP 57-10177 and JP 48-23617 on the August 30, 2007 IDS Form and JP 2-185954 and JP 60-162726 on the March 30, 2007 IDS Form.

The undersigned spoke to Examiner Yee on November 20, 2007 regarding this matter. Examiner Yee said that copies of the English-language abstracts of the publications that were not considered should be resubmitted.

Submitted concomitantly herewith are the following:

- (1) an English-language translation of JP 48-23617;
- (2) an English-language translation of JP 49-7117; and
- (3) English-language abstracts for JP 2-185954 and JP 60-162726.

The Examiner is respectfully requested to consider and make of record the aforesaid Japanese patent publications.

The amendment to claims 1 and 17 of "when the C content is 0.55 wt%, the Cr content is 0.3 wt% or more and when the C content is 1.5 wt%, the Cr content is 1.8 wt% or less," is supported by the paragraph bridging pages 17 and 18 and the first full paragraph on page 20 of the present specification.

With respect to the objection to claim 15 under 37 CFR 1.75 (see the middle of page 15 of the Office Action), claim 15 was amended to depend on claim 13.

Withdrawal of the objection to claim 15 is thus respectfully requested.

Claims 1, 10, 18 and 19 were rejected under 35 USC 112, second paragraph, for the reasons stated in item nos. 3 to 11 on pages 2 and 3 of the November 14, 2007 Office Action.

The last line of claim 1 was amended to recite "solid-dissolved carbon" as suggested by the Examiner in item no. 5 near

the bottom of page 2 of the Office Action.

Claim 18 was amended to respond to item no. 6 at the bottom of page 2 of the Office Action.

Claim 19 was amended to address item no. 7 at the top of page 3 of the Office Action.

Claim 10 was amended following the Examiner's suggestion in item no. 11 on page 3 of the Office Action.

Claims 1, 3 to 15, 17 to 20 and 22 were rejected under 35 USC 112, first paragraph, for allegedly failing to comply with the written description requirement for the reasons set forth in item no. 14 on pages 3 to 4 of the November 14, 2007 Office Action.

The Examiner took the position that the recitation in the claims of the formula " $0.55 \leq \text{Cr wt\%/C wt\%} \leq 1.2$ " raised a new issue matter, i.e., subject matter that is not supported by the specification.

Claims 1, 11, 12 and 17 were amended to delete the aforesaid formula.

Withdrawal of each of the 35 USC 112 rejections is therefore respectfully requested.

With respect of Rule 116, entry of the above amendments is respectfully requested, since such amendments are in reply to the 35 USC 112 rejections set forth in the Final Rejection. The amendments also do not introduce any new issues.

Claims 1 and 3 to 15, 17 to 20 and 22 were provisionally rejected on the grounds of obviousness-type double patenting as being unpatentable over the claims of application Serial No. 10/790,959.

A TERMINAL DISCLAIMER, which identifies Serial No. 10/790,959, is being filed concomitantly herewith.

Withdrawal of the double patenting rejection is thus respectfully requested.

Applicants are pleased to note that it was stated in item no. 25 on page 7 of the Office Action that claims 8 to 15 are patentable over Monma et al.

Claims 1, 3 to 7, 17 to 20 and 22 were rejected under 35 USC 103 as being unpatentable over USP 3,663,314 to Monma et al. in view of US 2002/0029597 to Choe et al. for the reasons indicated in item no. 18 on pages 5 to 6 of the Office Action. The

Examiner's reasons for this rejection were stated to be as set forth in the March 1, 2007 Office Action.

The reasons why the Examiner maintained this rejection were stated in item nos. 20 to 24 on pages 6 to 7 of the Office Action.

It was admitted in the Office Action that Monma et al. do not teach a Cr concentration in cementite of 2.5 to 10 wt%, retained austenite and/or pearlite as recited in applicants' claims.

It was admitted in the previous Office Action of March 1, 2007 that a prior austenite grain size of ASTM 10 or higher recited in applicants' claim 6 is not taught by Monma et al.

It was admitted in the previous Office Action of December 8, 2005 that the prior art does not teach a quenched hardened layer containing 0.1 to 1.5 microns, as recited in applicants' claim 3.

It was admitted in the previous Office Action of March 1, 2007 that the prior art does not teach shot peening as a finishing step to produce a residual compressive stress on the surface of the rolling bearing element, as recited in applicants' claims 10 to 15, 20 and 22.

It was admitted in the previous Office Action of March 1, 2007 that the prior art does not teach the DI formula recited in applicants' claims.

The condition for keeping the Cr concentration in the cementite, i.e., when the C content is 0.55 wt%, the Cr content is 0.3 wt% or more and when the C content is 1.5 wt%, the Cr content is less than 1.8 wt% as recited in applicants' claims, is not taught or suggested by Monma et al. See the ratio of C to Cr in TABLE IV at the bottom of columns 3 to 4 of Monma et al.

A bearing steel according to Monma et al. is produced such that after the steel is entirely heated in a furnace, a member which has been thoroughly hardened by quenching is tempered. It is considered that based on the following steel composition disclosed in Monma et al. consisting of C: 0.55 to 0.78 wt%, Cr: 0.5 to 2.0 wt%, Mn: 1.00 to 2.00 wt% and Si: 1.0 to 2.0 wt%, that there is a high risk for distortion during quenching or quenching crack.

According to applicants' claims, only a surface layer of a rolling element is case-hardened by induction hardening. More specifically, some of applicants' present claims relate to a gear

member in which a quench hardened layer is formed along a tooth profile. Monma et al. do not teach or suggest a steel composition suitable for induction hardening or a quench-hardened layer. Monma et al. also do not teach or suggest information relating to how to obtain a martensite structure (carbon concentration).

US 2002/0029597 to Choe et al. is directed to a shot peening technique and teaches a position of the shot peening to be aimed at end angles. However, applicants' claims 1 to 12 are directed to a case-hardened rolling element and applicants' claims 17 to 21 are directed to a method for producing the same. Therefore, the applicants disagree that applicants' present claims are obvious in view of USP 3,663,314 and US 2002/0029597.

Applicants' claims 13, 14, 15 and 22 are directed to shot peening. US 2002/0029597 teaches, in a table (see paragraph [0023]), angles of a nozzle; compressive residual stress; and depth of compressive residual stress. However, these are test results in order to further deepen the depth of the compressive residual stress in view of the strength required of bevel gears.

Choe et al. do not teach or suggest improving the bending fatigue strength and the pitching stress.

Withdrawal of the 35 USC 103 rejection is thus respectfully requested.

Reconsideration is requested. Allowance is solicited.

An INFORMATION DISCLOSURE STATEMENT is being filed concomitantly herewith.

If the Examiner has any comments, questions, objections or recommendations, the Examiner is invited to telephone the undersigned at the telephone number given below for prompt action.

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Respectfully submitted,



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- Encs.: (1) PETITION FOR EXTENSION OF TIME
(2) NOTICE OF APPEAL
(3) TERMINAL DISCLAIMER
(4) English-language translation and English-language abstract of previously cited Japanese patent publications
(5) INFORMATION DISCLOSURE STATEMENT



Request for Patent

July 30, 1971

Commissioner of Patent Office

Takehisa Doi

1. Title of the Invention

5 Method for Producing High Strength Steel With High
Hardness

2. Inventors

Address 10-11, Yaesaki-cho, Hiratsuka-shi, Kanagawa-ken
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Name Masaaki YONEHARA (one other)

5. Items of documents enclosed

- 20 (1) Specification 1
 (2) Drawing 1
 (3) Power of attorney 1
 (4) Copy of application form 1

(19) Japan Patent Office (JP)

25 Publication of Patent Application

(21) Application Number 47-46424

(11) Publication Number 48-23617

(43) Date of Publication of Application: March 27, 1973

Request for Examination: Filed (3 pages in total)

30 Request for Examination: Filed

Intraoffice Reference Number

6327-42

6659-42

(52) Domestic Classification

35 10 J183

10 J172

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SPECIFICATION

1.TITLE OF THE INVENTION

Method for Producing High Strength Steel With High Hardness

2.CLAIMS

15 1. A method for producing a high strength steel with high
hardness comprising the steps of rapidly heating steel
comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less
of Mn, 0.4 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less
of Cr at a rate of 15°C/min or less up to 800 to 850°C directly
20 above an A_{c1} or A_{c3} transformation temperature, quenching the
steel within 15 minutes after the steel reaches a quenching
temperature, and tempering the steel at a temperature of about
200°C or lower.

3.DETAILED DESCRIPTION OF THE INVENTION

25 The present invention primarily relates to a method for
producing a high strength steel with high hardness used for
wear-resistant members of large equipment such as construction
machines and industrial machines.

30 Though a conventional hardened steel, for example a
carbon tool steel, can yield very high hardness since it
contains as much as 0.8 to 1.5% of carbon, it has a disadvantage
of lacking toughness. Therefore, it is suitable for using as
wear-resistant members of a large machine in sections where
particularly high stress is not exerted, but in sections where
35 high stress is exerted, since members having high toughness have

to be used even at the expense of wear resistance, there was inconvenience that this kind of members generally wear early and have to be often replaced.

5 The present invention was made in view of the above state of the art, and it is an object of the present invention to provide a method for producing a high strength steel with high hardness which enhances the toughness of a hardened steel with high without reducing hardness to improve the above-mentioned defects of conventional hardened steels.

10 Hereinafter, the method for producing the high strength steel with high hardness, which is an example of the present invention, will be described in detail. Steel comprising 0.50 to 1.4% of carbon (C), 1.3% or less of silicon (Si), 1.3% or less of manganese (Mn), 0.4 to 2.0% of nickel (Ni), 0.30% or
15 less of molybdenum (Mo) and 1.0% or less of chromium (Cr) (hereinafter, denoted by an atomic symbol) is normalized once by the same method as conventional one, and then the steel is rapidly heated at a rate of about 15°C/min or more up to 800 to 850°C directly above an A_{c1} or A_{c3} transformation temperature
20 to prevent the dissolution of carbide in austenite from adequately proceeding, and the steel is quenched within 15 minutes after the steel reaches a quenching temperature. Next, the steel is tempered at a temperature of 200°C or lower, for example about 130°C, after quenching and thereby the high
25 strength steel with high hardness is obtained. The strength was compared between the obtained high strength steel with high hardness and a conventional carbon tool steel, for example, SK 3, to obtain the results shown in Fig. 1. That is, in the present invention, by adding Ni in the steel containing a large amount
30 of carbon, rapidly heating and quenching the steel by a means such as high frequency induction heating or the like, the dissolution of carbide in austenite is controlled to reduce an amount of carbon in martensite, and consequently a hardened structure consists of low carbon martensite and residual
35 carbide, high hardness can be attained by enhanced dispersion

of the residual carbide and less residual austenite, and toughness is improved by low carbon martensite containing Ni.

Relationships between hardness and strength, deflection, absorbed energy are compared between the hardened steel in which
5 toughness is enhanced by the above-mentioned addition of a large amount of Ni and special quenching and the conventional hardened steel to obtain Fig. 2. As is apparent from this Figure, it is clear that if having the same hardness as the conventional hardened steel, the hardened steel of the present invention is
10 extremely superior in all of a breaking load, a deflection, and absorbed energy and the toughness is enhanced. In addition, the conventional hardened steel contains little Ni or does not contain Ni at all and has a small quenching rate, and symbols in Figures represent the difference between carbon contents and
15 solidly shaded symbols represent conventional hardened steels. As described above, the present invention is characterized by rapidly heating steel comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less of Mn, 0.4 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less of Cr by a means such as high frequency
20 induction heating or the like, and then tempering the steel at a temperature of about 200°C or lower, and by adding Ni to a high carbon steel and rapidly quenching the steel, the dissolution of carbide in austenite is controlled and thereby an amount of carbon in martensite is reduce, and consequently
25 a high strength steel with high hardness consisting of low carbon martensite and residual carbide can be attained, and toughness is significantly improved by low carbon martensite while maintaining the hardness of the high carbon steel by enhanced dispersion of carbide and less residual austenite, and
30 the present invention exerts excellent effects particularly when it is used in wear-resistant members to which excessive stress is.

4.BRIEF DESCRIPTION OF THE DRAWINGS

Drawings represent an example of the present invention,

Fig. 1 is a bar chart showing a comparison of the strength of the present invention and a conventional hardened steel, and Figs. 2 are diagrams showing relationships between hardness and strength, deflection, absorbed energy.

5 Fig. 1

- ① Breaking Load (kg)
- ② Deflection (mm)
- ③ Absorbed Energy (kg·m)

Fig. 2

- 10 ① Breaking Load (kg)
- ② Deflection (mm)
- ③ Absorbed Energy (kg·m)
- ④ Conventional
- ⑤ Present Invention

15

Amendment (Voluntary)

August 14, 1972

Commissioner of the Patent Office: Takehisa INOUE

1. Indication of the Case

5 Application Number 46-56709

2. Title of the Invention

Method for Producing High Strength Steel With High Hardness

3. Person Amending a Description: Komatsu Ltd.

Relation to the Case: Applicant for Patent

10 2-3-6, Akasaka, Minato-ku, Tokyo

4. Attorney: Masaaki YONEHARA (one other)

Seiko Toranomom Bldg. 13, Shibakotohira-cho, Minato-ku, Tokyo.

5. Date of Order for Amendment: Voluntary Amendment

6. Contents of Amendment

15 See the separate sheet attached herewith.

(1) Description of 2. CLAIMS in the present specification
attached is amended as follows.

A method for producing a high strength steel with high
hardness comprising the steps of rapidly heating steel
20 comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less
of Mn, 0.40 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less
of Cr at a rate of 15°C/min or more directly above an A_{c1} or
 A_{c3} transformation temperature, quenching the steel within 15
minutes after the steel reaches a quenching temperature, and
25 tempering the steel at a temperature of about 200°C or lower.

Request for Patent

July 30, 1971

Commissioner of Patent Office Takehisa Doi

1. Title of the Invention

5 Method for Producing High Strength Steel With High
Hardness

2. Inventors

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10 3. Applicant

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Representative Ryoichi Kawai

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Minato-ku, Tokyo

Name Masaaki YONEHARA (one other)

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(19) Japan Patent Office (JP)

25 Publication of Patent Application

(21) Application Number 47-46424

(11) Publication Number 48-23617

(43) Date of Publication of Application: March 27, 1973

Request for Examination: Filed (3 pages in total)

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Intraoffice Reference Number

6327-42

6659-42

(52) Domestic Classification

35 10 J183

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6. Other Inventors and Representative

(1) Inventor

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Name Tadashi Hamamoto (one other)

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SPECIFICATION

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2.CLAIMS

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comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less
of Mn, 0.4 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less
of Cr at a rate of 15°C/min or less up to 800 to 850°C directly
20 above an A_{c1} or A_{c3} transformation temperature, quenching the
steel within 15 minutes after the steel reaches a quenching
temperature, and tempering the steel at a temperature of about
200°C or lower.

3.DETAILED DESCRIPTION OF THE INVENTION

25 The present invention primarily relates to a method for
producing a high strength steel with high hardness used for
wear-resistant members of large equipment such as construction
machines and industrial machines.

Though a conventional hardened steel, for example a
30 carbon tool steel, can yield very high hardness since it
contains as much as 0.8 to 1.5% of carbon, it has a disadvantage
of lacking toughness. Therefore, it is suitable for using as
wear-resistant members of a large machine in sections where
particularly high stress is not exerted, but in sections where
35 high stress is exerted, since members having high toughness have

to be used even at the expense of wear resistance, there was inconvenience that this kind of members generally wear early and have to be often replaced.

5 The present invention was made in view of the above state of the art, and it is an object of the present invention to provide a method for producing a high strength steel with high hardness which enhances the toughness of a hardened steel with high without reducing hardness to improve the above-mentioned defects of conventional hardened steels.

10 Hereinafter, the method for producing the high strength steel with high hardness, which is an example of the present invention, will be described in detail. Steel comprising 0.50 to 1.4% of carbon (C), 1.3% or less of silicon (Si), 1.3% or less of manganese (Mn), 0.4 to 2.0% of nickel (Ni), 0.30% or
15 less of molybdenum (Mo) and 1.0% or less of chromium (Cr) (hereinafter, denoted by an atomic symbol) is normalized once by the same method as conventional one, and then the steel is rapidly heated at a rate of about 15°C/min or more up to 800 to 850°C directly above an A_{c1} or A_{c3} transformation temperature
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30 of carbon, rapidly heating and quenching the steel by a means such as high frequency induction heating or the like, the dissolution of carbide in austenite is controlled to reduce an amount of carbon in martensite, and consequently a hardened structure consists of low carbon martensite and residual
35 carbide, high hardness can be attained by enhanced dispersion

of the residual carbide and less residual austenite, and toughness is improved by low carbon martensite containing Ni.

Relationships between hardness and strength, deflection, absorbed energy are compared between the hardened steel in which
5 toughness is enhanced by the above-mentioned addition of a large amount of Ni and special quenching and the conventional hardened steel to obtain Fig. 2. As is apparent from this Figure, it is clear that if having the same hardness as the conventional hardened steel, the hardened steel of the present invention is
10 extremely superior in all of a breaking load, a deflection, and absorbed energy and the toughness is enhanced. In addition, the conventional hardened steel contains little Ni or does not contain Ni at all and has a small quenching rate, and symbols in Figures represent the difference between carbon contents and
15 solidly shaded symbols represent conventional hardened steels. As described above, the present invention is characterized by rapidly heating steel comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less of Mn, 0.4 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less of Cr by a means such as high frequency
20 induction heating or the like, and then tempering the steel at a temperature of about 200°C or lower, and by adding Ni to a high carbon steel and rapidly quenching the steel, the dissolution of carbide in austenite is controlled and thereby an amount of carbon in martensite is reduce, and consequently
25 a high strength steel with high hardness consisting of low carbon martensite and residual carbide can be attained, and toughness is significantly improved by low carbon martensite while maintaining the hardness of the high carbon steel by enhanced dispersion of carbide and less residual austenite, and
30 the present invention exerts excellent effects particularly when it is used in wear-resistant members to which excessive stress is.

4.BRIEF DESCRIPTION OF THE DRAWINGS

Drawings represent an example of the present invention,

Fig. 1 is a bar chart showing a comparison of the strength of the present invention and a conventional hardened steel, and Figs. 2 are diagrams showing relationships between hardness and strength, deflection, absorbed energy.

5 Fig. 1

- ① Breaking Load (kg)
- ② Deflection (mm)
- ③ Absorbed Energy (kg·m)

Fig. 2

- 10 ① Breaking Load (kg)
- ② Deflection (mm)
- ③ Absorbed Energy (kg·m)
- ④ Conventional
- ⑤ Present Invention

15

Amendment (Voluntary)

August 14, 1972

Commissioner of the Patent Office: Takehisa INOUE

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5 Application Number 46-56709

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3. Person Amending a Description: Komatsu Ltd.

Relation to the Case: Applicant for Patent

10 2-3-6, Akasaka, Minato-ku, Tokyo

4. Attorney: Masaaki YONEHARA (one other)

Seiko Toranomom Bldg. 13, Shibakotohira-cho, Minato-ku, Tokyo

5. Date of Order for Amendment: Voluntary Amendment

6. Contents of Amendment

15 See the separate sheet attached herewith.

(1) Description of 2. CLAIMS in the present specification
attached is amended as follows.

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hardness comprising the steps of rapidly heating steel
20 comprising 0.50 to 1.40% of C, 1.3% or less of Si, 1.3% or less
of Mn, 0.40 to 2.0% of Ni, 0.30% or less of Mo, and 1.0% or less
of Cr at a rate of 15°C/min or more directly above an A_{c1} or
 A_{c3} transformation temperature, quenching the steel within 15
minutes after the steel reaches a quenching temperature, and
25 tempering the steel at a temperature of about 200°C or lower.



Request for Patent

May 12, 1972

Commissioner of Patent Office Takehisa Doi

1. Title of the Invention Wear Resistant Steel

5 2. Inventors

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 Representative Masayoshi Kawai

4. Items of documents enclosed

 (1) Specification 1

 (2) Drawing 1

15 (3) Copy of application form 1

 (4) Application of request for examination 1

5. Number of Inventions described in the scope of the claims:

2

20 (19) Japan Patent Office (JP)

 Publication of Patent Application

 (11) Publication Number 49-7117

 (21) Application Number 47-46424

 (21) Date of Publication: January 22, 1974

25 (22) Application Date: May 12, 1972

Request for Examination: Filed (7 pages in total)

Intraoffice Reference Number

6659-42

6378-42

30 (52) Domestic Classification

10 J172

10 S2

SPECIFICATION

1. TITLE OF THE INVENTION

Wear Resistant Steel

2. CLAIMS

5 1. A wear-resistant steel having a microstructure formed by uniformly and finely dispersing a carbonitride of one or more of 0.5 to 5.0% of titanium, zirconium, niobium, tantalum and vanadium in the steel containing 1.0% (% by weight, same as above) or less of carbon, 0.10 to 2.50% of silicon and 0.30
10 to 14.0% of manganese.

 2. The wear-resistant steel according to claim 1, wherein said wear-resistant steel contains 0.20% or less of phosphorus or boron and one or more of 0.30 to 30.0% of chromium, 0.10 to 5.0% of molybdenum and 0.40 to 25.0% of nickel together.

15 3. DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to steel provided with an excellent wear resistance by uniformly finely dispersing a carbonitride.

 In steel for structural for various machines generally
20 used in the location of hard wear and steel for molds used for various molding/forming, the wear resistance of steel is the most important characteristic, and various wear-resistant steels have been hitherto searched and developed. These steels are often exposed to elevated temperatures or corrosive
25 environments to be used, and in this case, wear-resistant steels, which is additionally provided with heat resistance or corrosion resistance, are required, but it is common that addition of such a characteristic practically causes apparent wear amount to increase as a synergistic effect.

30 The steel of the present invention has been formed by noting that steel in which a carbonitride of one or more of titanium, zirconium, niobium, tantalum and vanadium is uniformly dispersed finely has excellent wear resistance, and it is characterized in that the steel prepared by employing a
35 lower alloy steel than existing wear-resistant steels as an

matrix and dispersing the above-mentioned carbonitride in the lower alloy steel has outstandingly excellent wear resistance, and heat resistance and corrosion resistance together.

Hereinafter, the wear-resistant steel of the present invention will be described in detail based on Figs. 1 to 4.

The steel of the present invention is produced by adding elements to form a carbonitride to molten steel in which carbon amount has been brought into excessive compared to oxygen, nitrogen and sulfur quantities in advance to initiate a preferential reaction of these elements and the carbon, and dispersing uniformly and precipitating the resulting solid phase carbide together with nitride, and this carbonitride obtained needs to impart excellent hardness to steel and to be stable even in use conditions such as elevated temperatures and corrosive environments. Examples of elements composing the carbonitrides satisfying these conditions include mono-carbonitrides or composite carbonitrides of one or more of titanium, zirconium, niobium, tantalum and vanadium. Further, in such materials of carbonitride dispersed type, sizes, uniformity and a dispersion amount of dispersed particles are important factors to influence the characteristics of the materials, and it became clear that in order to improve the characteristics, it is effective to add phosphorus of 0.2% or less and it is desirable to add boron of 0.2% or less to preferentially form boron nitride in molten steel. From the description described above, it is apparent that the steel of the present invention can be produced by an industrial mass production method.

Next, in the steel of the present invention, a species and a required amount of the carbonitride uniformly dispersed in steel and components and a required amount of a matrix of the steel in which the carbonitride is dispersed will be described.

Fig. 1 shows a relationship between a dispersion amount of a carbonitride and relative wear resistance (wear in the case

where a dispersion amount is zero is taken as 1). It is found from Fig. 1 that the relative wear resistance is rapidly improved near the position where the dispersion amount of a carbonitride is 0.5% regardless of a steel species and a contact pressure. In addition, the dispersion amount of a carbonitride is determined based on the wear resistance requirement, but it is necessary to take the conditions of the occurrence of wear, particularly the conditions of the occurrence of chipping, into account. That is, when a contact pressure is low, the chipping does not occur, but when the contact pressure is high, the chipping comes to occur in a 1% chromium system if the dispersion amount of a carbonitride is 3.0% or more. However, it was observed that the tendency to produce this chipping does not appear in at least a range where the dispersion amount of a carbonitride is 5% or less in a high-concentration chromium-molybdenum system. And, it is observed that the relative wear resistance is almost saturated near the position where the dispersion amount of a carbonitride is 4% regardless of a steel species and a contact pressure. Therefore, in the steel of the present invention, the dispersion amount of a carbonitride was set at 0.5 to 5%.

Next, chemical components of a matrix in which the carbonitride is dispersed will be described.

An amount of carbon required for producing the carbonitride in the steel is 0.1 to 1.0%, but since this amount of carbon is all consumed for producing the carbonitride, the hardness of the matrix remains at 150 to 250 Hv and this amount of carbon does not help the hardness of the steel of the present invention increase. It is natural that the steel of the present invention has excellent wear resistance even in a range of low hardness compared with existing steel, but in order to make it possible to widely use the steel of the present invention in place of existing wear-resistant steels and to adequately utilize the excellent wear resistance of the steel of the present invention, it is necessary at least to attain hardness

after heat treatment equal to existing steels, and for this purpose, it is necessary to appropriately add a carbon amount of up to 1.0% according to intended use in addition to the carbon amount required for producing the carbonitride.

5 In the steel of the present invention, in order to prevent chipping and have corrosion resistance, it is effective to add chromium and molybdenum. When the dispersion amount of a carbonitride is 2% or less and corrosion resistance is particularly not required, it is not particularly necessary to
10 add these elements, but when the dispersion amount of a carbonitride is 2% or more, it becomes necessary to add 0.3% or more of chromium and 0.1% or more of molybdenum to prevent chipping, and further when corrosion resistance has to be additionally provided for the steel, it becomes necessary in
15 accordance with use conditions to add chromium so as to contain up to 30% and molybdenum so as to contain up to 5% to the steel as is apparent from Fig. 2 which shows the results of investigating steel's corrosion resistance by changing a chromium amount and a molybdenum amount.

20 Further, the wear resistance of the steel of the present invention can be further improved by bringing the matrix into an austenite structure, but in this case, the wear resistance of the steel of the present invention can be achieved by adding nickel so as to contain up to 25% under the coexistence with
25 a chromium amount up to 30%, and can be achieved by adding manganese so as to contain at least 14% under the coexistence with carbon as is apparent from Fig. 3 showing a relationship between a manganese amount and a carbon amount required for bringing the matrix into an austenite structure.

30 Further, as for a silicon amount, if a purpose is just to melt normally sound steel to enhance its softening resistance, it is only necessary for 0.10 to 0.80% of silicon to coexist with 0.30 to 1.0% of manganese, but in order to improve the oxidation resistance of the steel of the present invention, it
35 becomes necessary to add chromium so as to contain up to 25%

as is apparent from Fig. 4 showing a relationship between the oxidation resistance and a silicon amount.

In addition to this, the impact resistance of the steel of the present invention can also be improved by adding a trace of nickel other than bringing the matrix into an austenite structure. That is, good impact resistance may be required in using the steel of the present invention for various wear-resistant materials, and as is apparent from Table 1 showing the results of investigating a relationship between a nickel amount and a Charpy impact value, impact resistance can be improved by adding 0.4% of nickel in a low alloy steel and about 3.0% of nickel even in a high alloy steel, and the impact resistance is proportionally improved when the nickel amount is further increased, and the impact resistance is extremely good when the steel becomes austenite.

Hereinafter, excellent wear resistance of the present invention and associated properties will be described supportively.

Example 1

Table 2 shows the results of comparing impact resistance and wear resistance between the steel of the present invention formed by dispersing 1.7% of a carbonitride of zirconium in the steel containing 0.40% of carbon, 0.35% of silicon and 0.75% of manganese as a principal alloy component and JIS SCM 3 by a 2 V-notch Charpy impact test and an abrasive wear test. Here, 420 of the steel of the present invention is a specimen, hardness of which is lowered by 100 Hv from that of SCM 3 and 502 is a specimen having hardness approximately equal to SCM 3. As is apparent from Table 2, the wear resistance of the steel 420 to be attained is 1.8 times higher than that of SCM 3 and the wear resistance of the steel 502 is about 4 times higher than that of SCM 3. Therefore, when hardness is lowered if impact resistance equal to a conventional steel is required and the hardness equal to a conventional steel is employed if steel having higher wear resistance is required, the steel of the

present invention becomes a wear-resistant material which is much more economical than the conventional steel.

Example 2

Table 3 shows the results of comparing contact wear amounts at a contact pressure of 96 kg/mm^2 between combinations of JIS SKD 61 most widely used as steel for molds, steel (dispersion type steel-I) formed by dispersing 3.0% of a composite carbonitride of titanium and zirconium in the steel containing 25% of chromium and 0.5% of molybdenum as a principal alloy component, and steel (dispersion type steel-II) formed by dispersing 3.6% of a composite carbonitride of titanium and tantalum in the steel containing 5.0% of chromium and 21% of molybdenum as a principal alloy component. As is apparent from Table 3, the steel of the present invention is significantly low in a contact wear amount compared with SKD 61 and particularly, a wear amount of a combination of the steels of the present invention is a half or less of that of a combination of SKD 61s.

Example 3

Various properties as a cast steel of the steel of the present invention formed by dispersing 3.7% of a carbonitride of titanium in the steel containing 15% of chromium, 2% of silicon, 0.7% of manganese, 2% of molybdenum and 3% of nickel as a principal alloy component were investigated to obtain the following results.

(1) Hardness after heat treatment

The steel of the present invention has hardness of $250 \pm 10 \text{ Hv}$ regardless of a tempering temperature

(2) Wear-resistant

In a contact wear test against SCH.11 according to JIS, a wear amount was one-fifth of SCH.11.

(3) Heat resistance

A degree of oxidation/corrosion at elevated temperature of the steel of the present invention was $0.034 \text{ mg/cm}^2/\text{h}$ at 1000°C and $0.18 \text{ mg/cm}^2/\text{h}$ at 1200°C , and the steel of the present

invention can be used for parts exposed to elevated temperatures of at least 1200°C.

(4) Corrosion resistance

5 The steel of the present invention has the corrosion resistance of 0.5 g/m²/day against the aqueous solution of chloride of pH 2.5 and can be used as a wear-resistant material exposed to an acid solution.

(5) Mechanical properties

Tensile strength: 74.3 kg/mm²
10 0.2% proof stress: 45.3 kg/mm²
Elongation: 21.8%
Charpy impact value (2 V-notch): 1.5 kgm/cm²

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the results of investigating
15 effects of a dispersion amount of a carbonitride of titanium dispersed in the steel of the present invention on wear resistance and chipping resistance on the steel containing 1% of chromium and 0.2% of molybdenum as a principal alloy component and the steel containing 20% of chromium and 2% of
20 molybdenum as a principal alloy component.

Fig. 2 is a diagram showing an addition amount of chromium and molybdenum required when the steel of the present invention is used in corrosive environments in terms of a passivating region in the most severe acid aqueous solution including
25 chlorine ions, and Fig. 3 is a diagram.

Fig. 3 shows a relationship between a manganese amount and a carbon amount required for bringing a structure of the steel into an austenite structure in order to improve the wear resistance of the steel of the present invention, and Fig. 4
30 is a diagram showing a relationship between a silicon amount and a degree of corrosion, which is effective for improving the oxidation resistance in the case where the steel of the present invention is exposed to elevated temperatures.

Table 1

- ① Symbol of specimen
- ② Chemical component (%)
- ③ Dispersed particle
- 5 ④ Hardness (Hv)
- ⑤ Charpy impact value (2 V-notch)
(kgm/cm²)

Table 2

- 10 ① Hardness (Hv)
- ② Charpy impact value (2 V-notch)
(kgm/cm²)
- ③ Wear rate (g)
- ④ Average
- 15 ⑤ Steel of the present invention

Table 3

- ⑥ Test number
- ⑦ Specimen A
- 20 ⑧ Kind of specimen
(Hardness)
- ⑨ Wear amount (g)
- ⑩ Specimen B
- ⑪ Dispersion type steel-I
- 25 ⑫ Dispersion type steel-II

図説

図 1

- ① Relative Wear Resistance
- 30 ② 1%Cr-0.2%Mo
(contact pressure 100 kg/cm²)
- ③ Dispersion Quantity of Carbonitride (%)

図 2 ~ 4

- ① Carbon Quantity (%)
- ② Manganese Quantity (%)
- ③ Casting without Change
- ④ 950°C Water Cooling
- 5 ⑤ Austenite Region
- ⑥ Molybdenum (%)
- ⑦ Chromium (%)
- ⑧ Passivation at a pH greater than 2.5
- ⑨ Passivation at a pH greater than 1.5
- 10 ⑩ Passivation at a pH greater than 0.5
- ⑪ Degree of Corrosion ($\text{mg}/\text{cm}^2/\text{hr}$)
- ⑫ in the Air of 1100°C
- ⑬ Silicon (%)

Amendment (Voluntary)

July 27, 1972

Commissioner of the Patent Office: Yukio MIYAKE

1. Indication of the Case

5 Application Number 47-46424

2. Title of the Invention

Wear Resistant Steel

3. Person Amending a Description: MITSUBISHI STEEL MFG. CO., LTD.

10 Relation to the Case: Applicant for Patent

Address 2-6-2, Ohtemachi, Chiyoda-ku, Tokyo

Name Masayoshi Kawai

4. Object for Amendment: Paragraph in DETAILED DESCRIPTION OF THE INVENTION

15 5. Contents of Amendment

A part of the descriptions of the present invention are amended as follows.

1. A word "chipping" on page 4, line 13 is amended to "pitching".

2. A word "chipping" on page 4, line 15 is amended to "pitching".

20 3. A word "chipping" on page 4, line 17 is amended to "pitching".

4. A word "chipping" on page 4, line 18 is amended to "pitching".

5. A word "chipping" on page 6, line 2 is amended to "pitching".

JP2185954

Publication Title:

CARBURIZED AND CASE-HARDENED STEEL AND ITS PRODUCTION

Abstract:

Abstract of JP2185954

PURPOSE:To manufacture a case hardening steel having superior fatigue characteristics by reducing respective contents of Gi, Mn, and Cr in a steel stock as a raw material, adding specific amounts of Nb, and carrying out new treatments of spheroidizing annealing and hardening after carburizing treatment at the time of manufacturing case hardening steel for machine parts. **CONSTITUTION:**As a case hardening steel for machine parts, a steel stock which has a composition containing, by weight, 0.15-0.35% C, (0.05% Si, <0.35% Mn, <0.10% Cr, 0.35-2.00% Mo, and 0.010-0.100% Nb or further containing, if necessary, one or more kinds among <3.50% Ni, <1.00% Cu, 0.010-0.100% Al, 0.01-0.30% V, 0.010-0.100% Ti, and 0.0003-0.0050% B is carburized and quenched to increase the amount of C in the surface and held in a carburizing atmosphere at a temp. between the Ac1 point and [Ac1 point + (Ac3 point - Ac1 point)X0.6] for 1-4hr. Subsequently, the above steel is slowly cooled at <=30 deg.C/hr cooling rate to undergo spheroidizing annealing, held at a temp. in the range between the Ac3 point and (Ac3+30 deg.C) for a short time, and then requenched. By this method, the case hardening steel in which C content in the surface layer is regulated to 0.50-1.50% and which has a martensitic structure containing spheroidal cementite and also has excellent fatigue strength can be obtained. Data supplied from the esp@cenet database - Worldwide

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File: JPAB

Aug 24, 1985

PUB-NO: JP360162726A

DOCUMENT-IDENTIFIER: JP 60162726 A

TITLE: METHOD FOR SURFACE-HARDENING TOOTHED PART OF RING GEAR OF FLYWHEEL

PUBN-DATE: August 24, 1985

INVENTOR-INFORMATION:

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KATO, SHINJI

US-CL-CURRENT: 148/586; 148/902

INT-CL (IPC): C21D 8/00; C21D 7/02

ABSTRACT:

PURPOSE: To improve the wear resistance and fatigue strength of the toothed part of a ring gear around the body of a flywheel by hardening and tempering the toothed part and hardening it by a physical surface hardening method.

CONSTITUTION: A steel or cast iron ring gear is placed around the cast iron body of a flywheel, and they are divided or united as one body to manufacture a flywheel. The toothed part of the ring gear is hardened by induction hardening or other method, or it is further tempered to strengthen the surface. Physical surface hardening such as shot peening or rolling is then carried out. The wear resistance and fatigue strength of the toothed part of the ring gear are improved.

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